Semi-annual Report for July - December, 1996
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Abstract

The algorithm-development activities at USF during the last half of 1996 have concentrated on field data collection and theoretical modeling. Five bio-optics experiments were conducted: one weekend cruise (TWIST) to Anclote Key, FL., one cruise in the Dry Tortugas area (Cobop 96) accompanied by a NOAA P3 airplane overflight, two cruises in the East China Sea, one in out flow of the Chesapeake Bay, and one in Gulf of Mexico (Loop Current, Dry Tortugas). Two abstracts were submitted for a conference presentation in Halifax, Canada. Four abstracts and papers were submitted for 4th International Conference, Remote Sensing for Marine and Coastal Environments in Orlando. Four abstracts were submitted to ASLO 97 in Santa Fe, New Mexico.

Tasks Accomplished:

1. Four research expeditions were completed:

a. Coastal Benthic Optical Properties (COBOP 96)

1) July 10 - July 24

2) ONR-funded ship time and aircraft overflight time

3) Three major transect lines over coral reef environments were studied along with one deep-water, oligotrophic station offshore used to calibrate airplane data.

4) This data set is useful for developing bottom-discrimination algorithms and to observe error induced by bottom

reflectance.

b. East China Sea (two cruises)

1) July 15 to August 12

2) Taiwan NSF-funded ship time

3) Transects from the Kuroshio onto the continental shelf and into

coastal plumes from rivers.

4) Test and modify Case II chl a algorithm for CDOM-rich waters.

c. Chesapeake Outflow Plume Experiment I (COPE I)

1) September 13 to 28

2) ONR-funded shiptime on R/V Seward Johnson

3) Transects from the mouth of Chesapeake Bay to Cape Hatteras

I) Test and modify Case II chl a algorithms for CDOM-rich waters.

d. TWIST cruise to Anclote Key, Florida

1) July 1996

2) ONR-funded shiptime on R/V Bellows

3) Gain knowledge about the phytoplanton population size distribution and understand the effects of path-length elongation factors on particle absorption from pads due to various sizes and types of phytoplankton.

e. Gulf of Mexico (Loop Current, Dry Tortugas)

1) November 14 to 17

2) MODIS-funded shiptime; cruise truncated due to weather

3) Transects from the Florida Keys into the Loop Current .

4) Test/modify Case I and Case II MODIS algorithms using OCTS data for the first time.

2. An abstract entitled " Protocols for R_{rs} measurements from clear to turbid waters " by Lee at el. was submitted to the Ocean Optics XIII conference in Halifax, Nova Scotia, Canada, Oct. 22-25, 1996 and was presented.

Remote-sensing reflectance (R_{rs}, ratio of the water-leaving radiance to downwelling irradiance just above the surface) and inherent optical properties of oceanic waters are important parameters for ocean optics. Due to surface reflectance of skylight, R_{rs} or water-leaving radiance can be difficult to quantify from above the surface under certain circumstances. It usually is derived by correcting for the reflected skylight in the above-water, measured, upwelling radiance using a theoretical Fresnel reflectance value (Quick-and-Easy method). The errors in derived R_{rs} using this method increase for coastal waters where the blue signals are low. We partition the skylight into Rayleigh and aerosol contributions, remove the Rayleigh contribution using the Fresnel reflectance relationship with observation angle, and correct the aerosol/glint contribution using an optimization algorithm. During the process, R_{rs} and in-water inherent optical properties are derived. For measurements at 45 sites made in the Gulf of Mexico and Arabian Sea with chl_a concentrations ranging from 0.07 to 49 mg/m^3, the derived R_{rs} and inherent optical property values were compared with those from in-water measurements. It was found that the ratios of $R_{rs}(440)/R_{rs}(550)$ were very consistent with in-water values (- 10% Root-Mean-Square-Difference for chl_a < 1.5 mg/m^3). Also, for chl_a < 1.5 mg/m^3, the Quick-and-Easy (Q&E) method derived R_{rs} as accurately as the optimization method.

3. A paper entitiled " Polarization of remote-sensing reflectance measured 90^o to the solar

plane" by Lee, Z.P., Carder, K.L., Peacock, T.G., Steward, R.G., was submitted to and presented at the Ocean Optics XIII conference in Halifax, Nova Scotia, Canada, Oct. 22-25, 1996.

Remote-sensing reflectance (ratio of the water-leaving radiance to the downwelling irradiance above the surface) was derived for measurements made in a plane 90^o to the solar plane and in a direction 30^o to nadir. These measurements, carried out to see if the water-leaving radiance in that direction is highly polarized, were made with and without a vertical polarizer in front of the sensor. For 28 pairs of measurements with chlorophyll_a concentrations ranging from 0.07 to 38 mg/m^3, sun angles from 18^o to 66^o from zenith, clear to cloudy skies, and for optically shallow and deep waters, we did not see significant variations between the polarized and unpolarized results after removal of reflected skylight. Statistical comparisons of polarized to unpolarized R_{rs} results provided R^2 values of 0.990, 0.998, and 0.999 with slopes 1.011, 0.981 and 1.009 for wavelengths at 440, 550 and 630 nm, respectively. These results suggest that although the under water light field is partially polarized, the water-leaving radiance 90^o to the solar plane and 30^o (22^o underwater) to nadir is not highly polarized.

4. Four papers have been submitted for presentation and publication at the Remote Sensing of Marine and Coastal Environment meeting in Orlando: ‘Skylight Correction of Video Images: An Airship Shadow Approach’ by M.L. Carder et al.; ‘Experimental Determination of Spectral Absorption by Iron-Bearing Aerosols: Applications to Remote Sensing Imagery’ by C. Cattrall et al.; ‘Remote Sensing Reflectance Algorithms Developed to Correct Underwater Coral Imagery for the Effects of Optical Depth and Turbidity’ by P.D. Pratt et al.; and ‘Bottom Depth and Type for Shallow Waters: Hyperspectral Observations from a Blimp’ by Z. Lee et al The last paper is summarized below:

In a study of a blimp transect over Tampa Bay (Florida), hyperspectral upwelling radiance over the sand and seagrass bottoms was measured. These measurements were converted to remote-sensing reflectances values. Using a shallow-water, remote-sensing-reflectance model, in-water optical properties, bottom depths, and bottom albedos were derived analytically and simultaneously by an optimization procedure. In the process, representative spectral shapes of sand and seagrass albedos were used. Also used was a model of spectral absorption by phytoplankton pigments. The derived bottom depths were compared with bathymetry charts and found to agree well. This study suggests that a low-flying blimp is a useful platform for the study and mapping of coastal water environments. The optical model as well as the data-reduction procedure used are practical for the retrieval of shallow water optical properties.

5. Two papers were submitted to ASLO 97 for presentation: ‘In Situ Optical Data Collected Aboard Unmanned Underwater Vehicles in Coastal Water’ by D.K. Costello et al.; and ‘Absorption Coefficients and the Path Elongation Factor: Influence on Remote Sensing of Shallow-Water Bathymetry’ by Lee, Z. P et al. The latter of these is synopsized below:

In passive remote sensing of shallow-water bathymetry, "effective" attenuation coefficients for the water body are traditionally used. In this study, the attenuation coefficient of the water body is explicitly expressed as the product of the absorption coefficient and an optical- path elongation factor. In the retrieval of bottom depth, it is found that one major source of error for clear waters comes from the "pure" water absorption coefficients used in the process. For a series of remote-sensing measurements made near Key West (Florida), results using the pure- water absorption of Smith and Baker, of Pope, and a mixture of Pope and Tam and Patel curves were compared. These show that the absorption curve of Smith and Baker leads to shallower bathymetric estimates. Also in this study, a spectral path-elongation factor was considered, with a spectral path elongation parameterization derived for use in future bathymetric studies.

6. A paper entitled ‘ Regulation of Ribulose Bisphosphate Carboxylase Gene Expression in Natural Phytoplankton Communities. II) lineage-specific mRNA in size fractions and euphotic zone profiles’ by S. L. Picard et al., Marine Ecology Progress Series, is in press.

To understand the composition and photosynthetic carbon fixing activities of natural phytoplankton communities, we have employed lineage-specific ribulose bisphosphate carboxylase (RubisCO) large subunit gene probes (rbcL) to examine RubisCO expression. The rbcL genes from Synechococcus PCC6301 (cyano) and from Cylindrotheca sp. (chromo) were used to examine levels of rbcL mRNA in specific size fractions (whole, <5 n m, <1 n m) in surface waters of the mouth of Tampa Bay (estuarine), West Florida Shelf (coastal), and from the offshore Gulf of Mexico. Using DNA purified from algal isolates, we have demonstrated that the cyano probe was specific for the chlorophyte/cyanobacterial RubisCO evolutionary lineage and the chromo probe was specific for the chromophyte evolutionary lineage (diatoms, prymnesiophytes, and other non-green microalgae). For coastal/estuarine environments, both cyno and chromo rbcL mDNA were predominately confined to the > 5 n m size fraction, whereas in offshore oligotrophic environments, the cyano mRNA was associated with smaller cells (< 1 n m). Similarly, ^{14}C carbon fixation rates and Chl a were predominately in the >5 n m fraction in coastal/estuarine environments, while in offshore environments, a greater percentage was present in the < 1 n m fraction. In profiles through the euphotic zone, cyano rbcL mRNA exhibited maximal values above the 65m at all stations, and in most cases, above 25m. In contrast, chromo rbcL mRNA increased with depth from undetectable levels in surface waters to its highest levels at or below the subsurface chlorophyll maximum(SCM), 67m or deeper. Carbon fixation rates were generally elevated in both surface waters and around the SCM. HPLC pigment analysis indicated an abundance of chromophytic algae in the deep euphotic zone while flow cytometry analysis showed an abundance of picoeucaryotes. Cyanobacteria-like cells (Synechococcus and Prochlorococcus) were more abundant in surface waters and at mid-depth. Such analysis are consistant with the rbcL gene probe patterns of euphotic zones offshore oligotrophic environments. This study demonstrates the utility of evolutionary lineage-specific gene probes for examining the expression of carbon fixing in phytoplankton which are important to the global biogeochemical process of photosynthetic carbon fixation. They also relate to particle size and its effect on the chlorophyll-specific absorption coefficient.

7. Jeniffer Patch attended the SeaWiFS Absorption Workshop in La Jolla, CA on December, 1996. The SeaWiFS Absorption Workshop took place at the Scripps Institution of Oceanography 9-13 December, 1996. The goal of this workshop was to compare protocols used by various labs for the determination of particulate, soluble, and phytoplankton absorption coefficients. The need for such a workshop was decided at the SeaWiFS Bio-optical workshop in March 1996, and the Primary Production workshop in June 1996. Of particular interest was the examination and measurement of the beta factor or path elongation factor for the filter pad technique (FPT). Comparing the numerous instruments operated by different labs and used for measuring absorption was another primary concern. Additional topics addressed were new techniques for measuring spectral particle absorption including the “filter transfer freeze” (FTF) method and the “transmission and reflection” methodology (Limnol. Oceanogr. 40(8): 1358-1368, 1995).

On the first day of the meeting, results were presented from previous work done by a few participants and from a similar workshop sponsored by Bigelow Laboratory in October, 1996. Topics discussed included how and if filter freezing is acceptable (Heidi Sosik), contamination of Milli Q water during long cruises (Greg Mitchell), species specific beta factors (Lisa Moore) and temperature/salinity effects on soluble absorption measurements (Scott Pegau).

Labwork during the first two days of the workshop involved instrument comparisons of filter pad and suspension absorption measurements. Six cultures of phytoplankton (duplicates of two volumes) were compared on seven spectrophotometers. Sample preparation was completed by one or two persons to eliminate any bias. The following tests were also run on each culture: HPLC, Coulter Counter and Fluorometric Chlorophyll. Preliminary results suggest that all of the spectrophotometers measured the absorption spectra of filter pads and (if feasible) suspensions similarly with a small amout of variability. The instruments without UV lamps performed poorly below 400nm as expected. The HP8452 and the Perkin-Elmer lambda 6 instruments exhibited noisier spectra as compared to the other spectrometers.

On the remaining three days of the workshop, different groups investigated issues in depth such as the two new measurement techniques mentioned above, soluble sample preparation and storage, beads and phase functions, wavelength dependence of beta, AC9 versus standard spectrophotometers and extraction techniques.

The group assigned to examine the various extraction techniques for separating phytoplankton absorption from detrital absorption included myself, Norm Nelson (PE lambda 6 with integrating sphere), Helmut Maaske (Elyptica) and Motoaki Kishino. We tested methanol, hot methanol, 50% NaClO (or bleach) and a 50:50 hot methanol/water solution for how well each solvent extracts pigments from *Thalassiosira pseudonana* (12/11), a natural sample collected from a small boat offshore from Scripps (12/12) and *Synechococcus sp.* (12/13). We tested extraction times of 3 minutes, 10 minutes and 30 minutes. (Note: not all treatments/ extraction times were done for each culture.) The results suggest that the bleach absorbs strongly at wavelengths less than 400nm, but this signal may be removed by rinsing the filter with water. This artifact was also found to appear in the absorption spectra of suspensions and cannot be removed. This is a concern for the “transmission and reflection” technique that should be investigated further. The hot methanol and cold methanol treatments performed similarly on the natural sample and the *Synechococcus sp.* culture. The hot methanol performed slightly better. Both methanol treatments were unsuccessful at removing the phycobilins from the blue-green algae as expected given the water-soluble nature of these pigments. The 50:50 hot methanol/water solution was completely ineffective at extracting pigments from the blue-green algae. Optimal extraction times varied depending on the type of sample examined. The methanol treatments (hot and cold; 3’, 10’ and 30’) performed similarly on the natural sample. The detrital spectra from bleaching the natural sample reduced in magnitude significantly with increasing extraction time.

8. A paper entitled "Pigment packaging and chlorophyll a-specific absorption in high-light oceanic waters" by Bissett at el. was revised and resubmitted to Limnology and Oceanography is in press .

The absorption of light by particles at a single wavelength, $a_{\varphi}(\lambda)$, is reduced with increased packaging of the light absorption material within these particles. This reduction can be described by the parameter Q*a:

$$Q_a(\lambda) = \frac{a_{\varphi}(\lambda)}{a_{sol}(\lambda)} = \frac{a_{\varphi}(\lambda)}{S\ A\ a_{om}(\lambda)}$$

where $a_{sol}(\lambda)$ is the theoretical maximum light absorption of the cellular material, a_{om}, in a completely dissolved state(solution). In practice, the estimations $a_{sol}(\lambda)$ for living phytoplankton are hampered by the process of removing the light absorptive material (pigments) from the organic matrix of the cell. The estimations of $a_{sol}(\lambda)$ can be further hampered by the destruction of the pigment-protein complexes when an organic solvent is used to strip the pigment from the cell. What is actually being measured by any of the current methods trying to determine $a_{sol}(\lambda)$ is $a_{om}(\lambda)$, i.e. the absorption of light by the pigment material in the organic medium of the experiment (methanol, acetone, Triton-X, etc.) The solvation factor, S, in the above equation is the ratio of the true $a_{sol}(\lambda)$ to the measured $a_{om}(\lambda)$.

We have developed an internally consistent measure of $a_{\varphi}(\lambda)$, $a_{om}(\lambda)$, chlorophyll *a* concentration, and pheopigment concentration to determine the value of $Q^* a \bullet S$. This relationship is used to determine a functional relationship for chlorophyll *a* absorption for high-light-adapted, natural phytoplankton populations in optically clear waters. The packaging effect in these waters is negligible at the red end of the spectrum. Exclusion of the weight-specific absorption of pheopigments and the assumption of a zero $a_{\varphi}(\lambda)$ at a zero pigment (chlorophyll *a* + pheopigment) concentration produces a misleading chlorophyll *a*-specific absorption and a false determination of pigment packaging. An algorithm is developed for predicting chlorophyll *a* concentration from $a_{ph}(675)$.

Anticipated Activities:

1. Relationships between temperature anomalies and the pigment-packaging effect and nutrients will be explored in order to reduce uncertainty in the chlorophyll algorithm. Bering Sea data and upwelling data from Arabian Sea , Montery Bay and East China Sea will be used in the analyses.

2. Identifying AVIRIS images containing well defined clouds and shadows will be attempted before the images have been calibrated and corrected for atmospheric effects learning methods(neural networks) using machine.

3. Two papers are in preparation by Lee et al.: a. "Removal of reflected sky-light and retrieval of in-water inherent optical properties using water remote-sensing reflectance". And b. "Polarization of remote-sensing reflectance measured at 90 degrees to the solar plane".

4. Research expeditions to be completed :

I. Florida Bay and Florida Strait cruise

II. January 18 to January 23

III. NOAA and LANDSAT funded ship time

IV. Transects from Florida Bay to Florida Strait

V. For Case II algorithm development with bottom not visible.

b. OCTS sea truth cruise

1. February 21 to March 2
2. NASA-funded ship time
3. Hawaii to North Pacific Ocean
4. Remote sensing reflectance technique comparison.

c. Florida Bay and Florida Strait cruise

1. March 3 to March 10
2. NOAA funded ship time
3. Transects from Florida Bay to Florida Strait
4. For Case II algorithm development with bottom not visible.

d. White-Sands Instrument Calibration

1. March 22 to March 26
2. NASA-funded trip
3. White Sand DOD missile range
4. Ground albedo measurement, clean air, low humidity enviornment for instrument intercalibration between USF and U. of Arizona.

e. South China Sea Cruise

1. April 15 to April 25
2. Taiwan NSF-funded ship time
3. Transects from Kuroshio onto the continental shelf and into coastal plumes from rivers.
4. Test and modify Case II chl a algorithm for CDOM-rich waters.